Assimilation of AIRS Data at NRL

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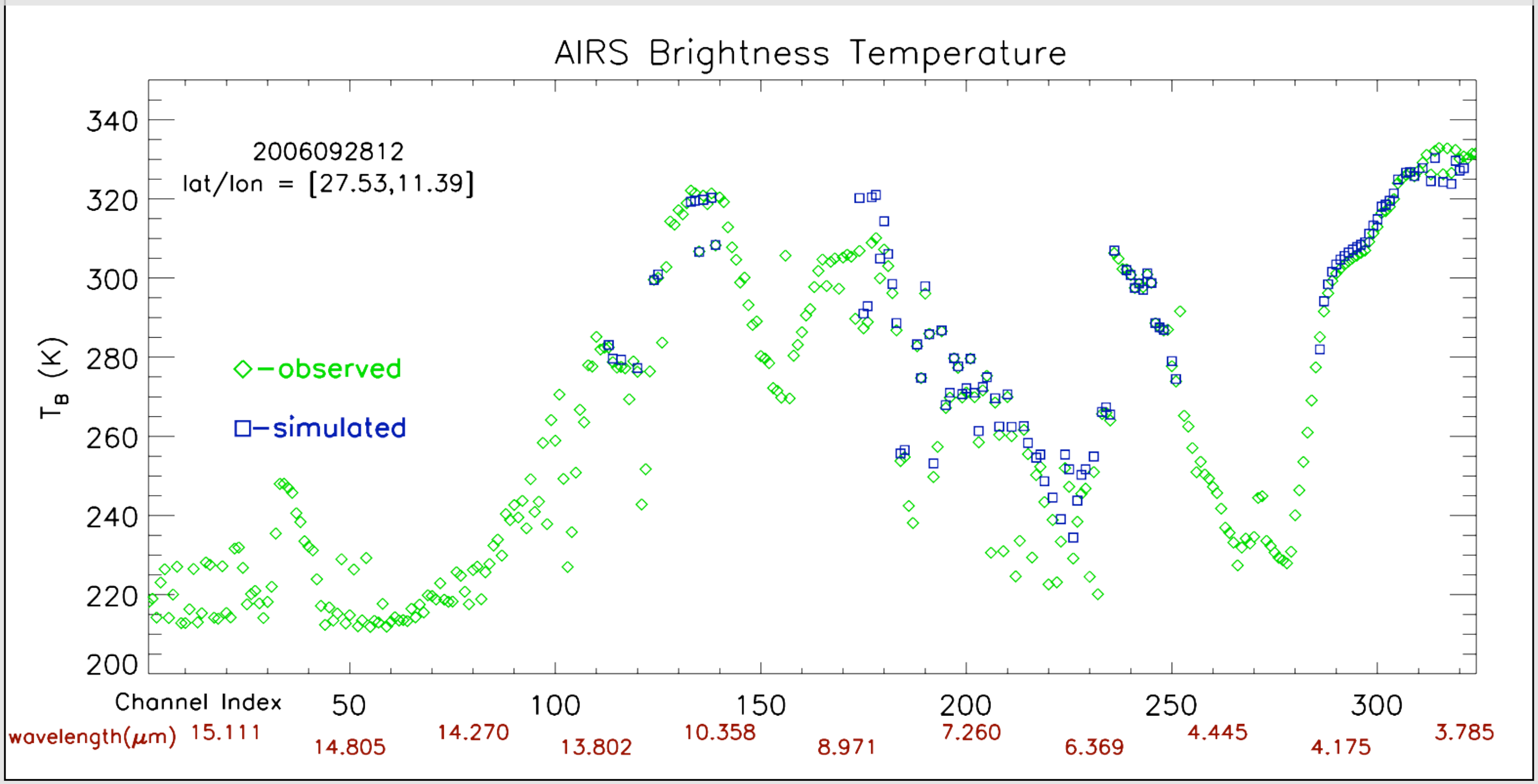
Data Use

- AIRS-324 channel subset, U1 and U2 alternate golfballs
- Co-located with AMSU/A sensor, simultaneous assimilation
- Thinned to approximately 300km resolution
- Channels with sensitivity above model top (4mb) rejected
- Ozone sensitive channels rejected
- Near-infrared channel rejected in daytime
- Approximately 4million observations per 6 hour watch before thinning and quality control

Channel Selection

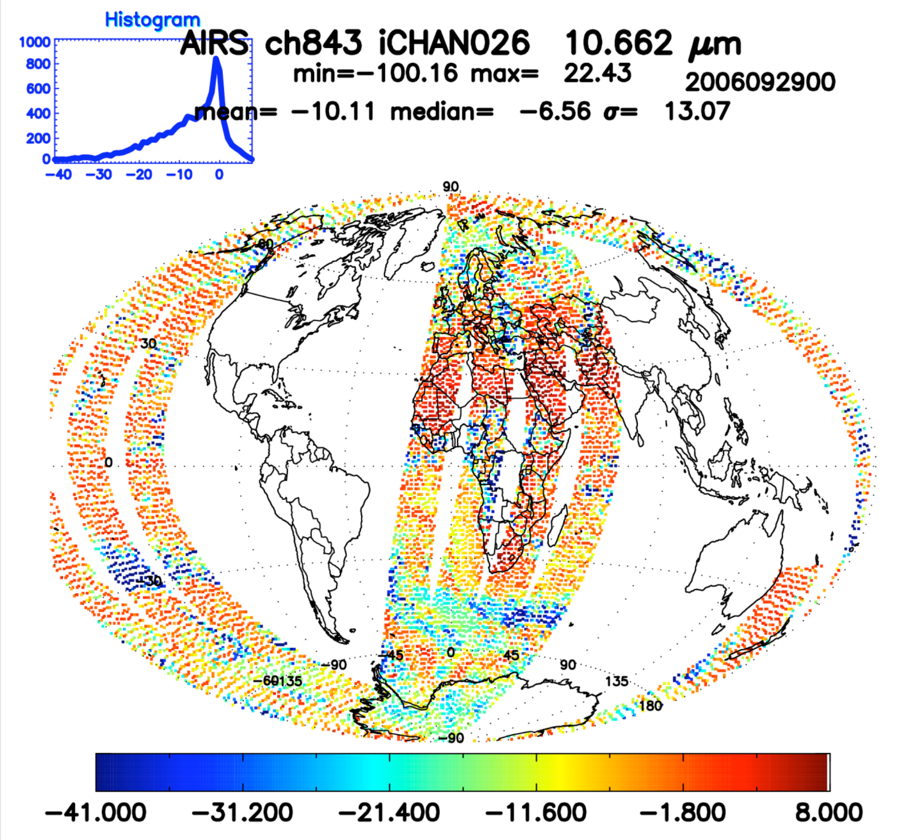
NOGAPS model top 4hPa, and no prognostic O_3

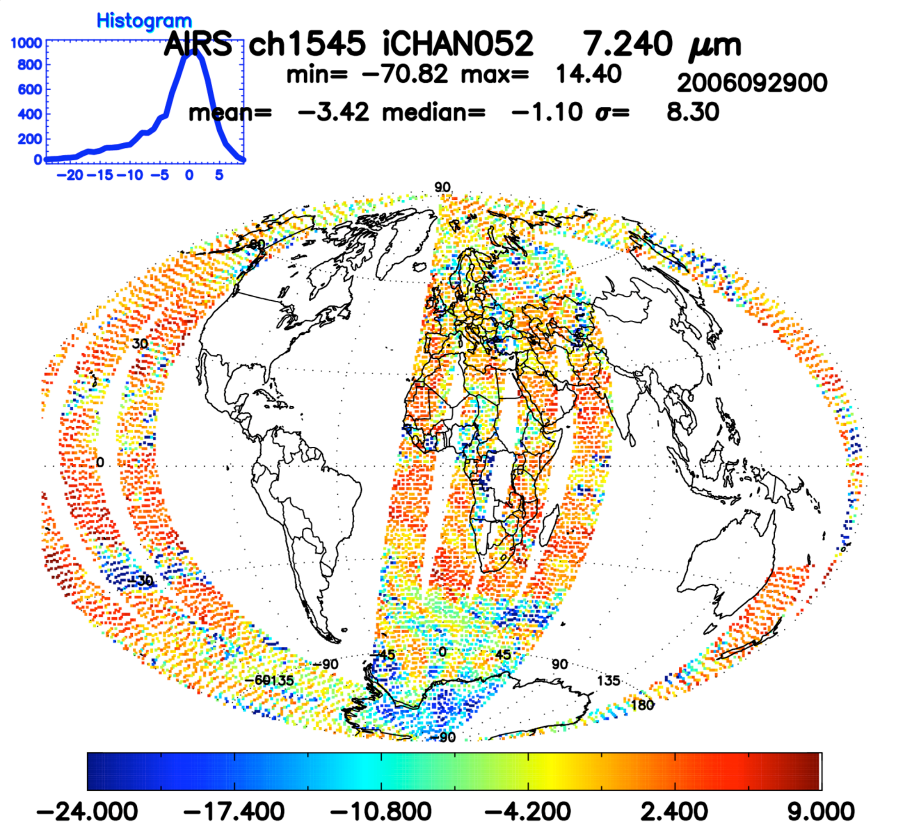
additional tools: **ECMWF & MSC operational lists, adjoint senstivities**



Data Thinning

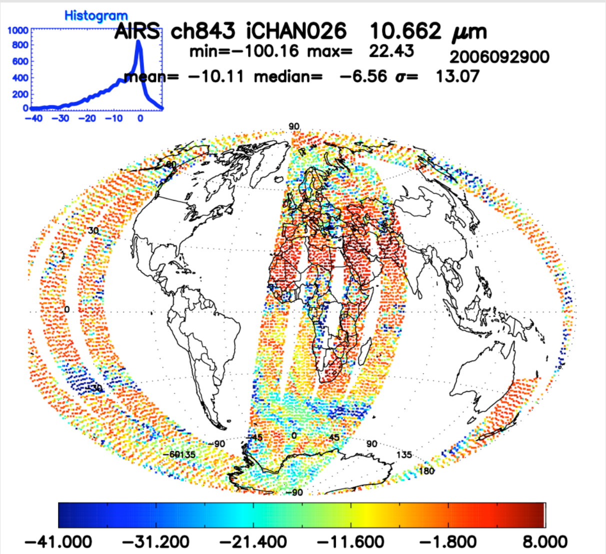
thinned to ~300km resolution

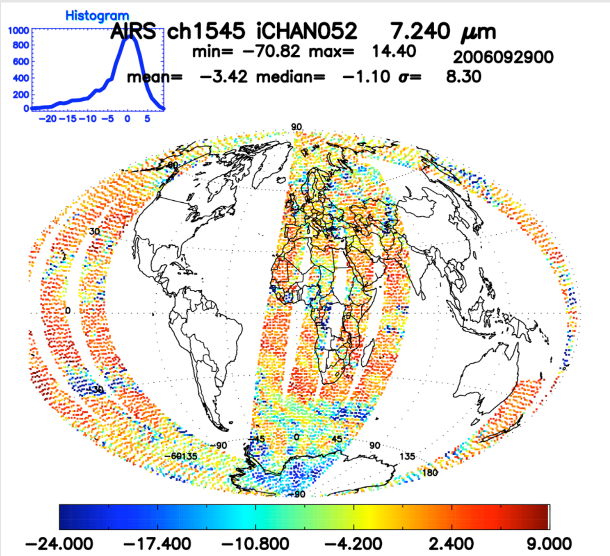




Quality Control

- Radiances modeled using JCSDA-CRTM
  - Histograms of observed minus simulated (ob-background)
  - Slope change in wavelength vs. (ob-background)*
  - Gross check on 2 window and 2 water vapor channels
  - Individual checks for each channel based on ob error





*A. McNally and P. Watts, 2003, *A cloud detection algorithm for high-spectral-resolution infrared sounders. Q. J. R. Meteorol. Soc.*, **209**, pp. 3411-3423.

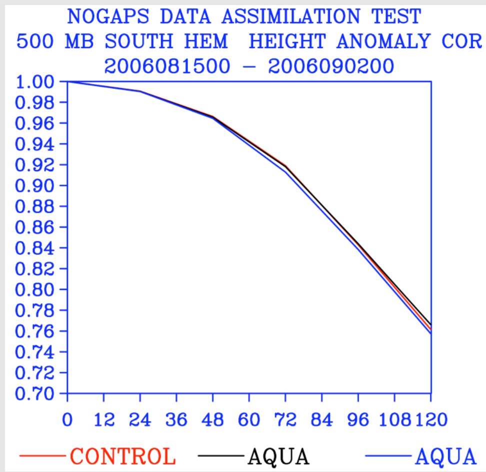
Forecast Impacts

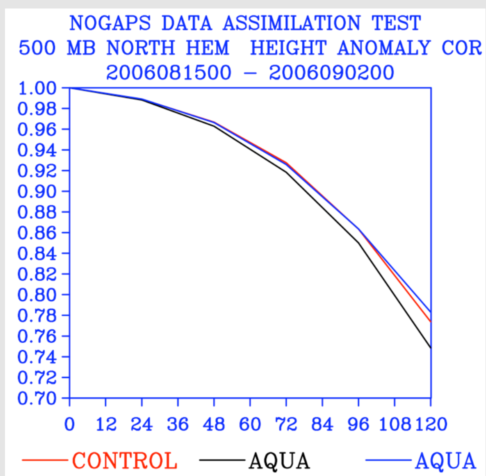
Anomaly Correlations

AQUA impacts

AIRS+AMSU
SH better
NH worse

AMSU only
SH slightly worse
NH better

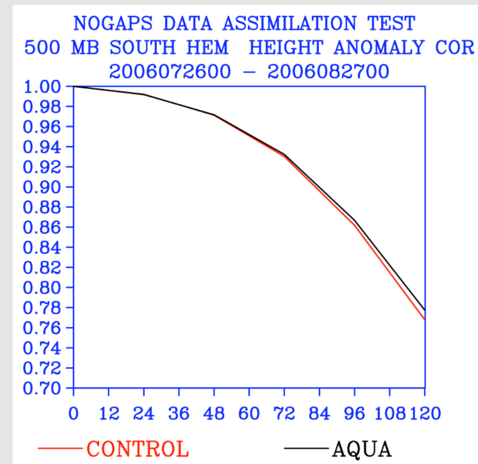


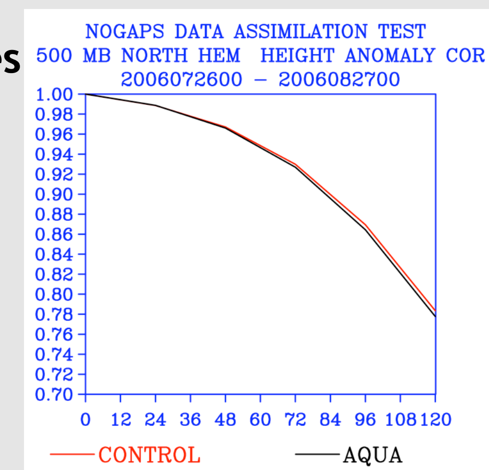


AQUA impacts
(ocean only)

AIRS+AMSU
SH better
NH slightly worse

ocean only improves
NH performance





Forecast Impacts

Tropical Cyclone

	==== ALL TROPICAL STORMS FOR 2006072600 TO 2006090200 ====								
		NOAA AMSU				NOAA AMSU + AQUA AMSU/AIRS			
	Tau	dslp1	#storms	ddis	#stroms	dslp2	#storms	ddis2	#storms
better	0	0.00	172	32.58	172	0.00	172	28.95	172
	12	1.34	151	51.32	154	1.23	153	48.09	156
	24	1.88	134	70.94	138	1.62	132	64.12	137
	36	2.21	116	93.59	122	1.93	113	84.72	119
	48	2.27	97	116.95	105	1.80	95	105.29	103
	60	1.97	80	136.43	90	1.66	79	128.08	89
	72	1.84	68	150.80	77	1.43	67	147.73	76
	84	1.54	57	169.46	66	1.09	56	167.87	65
worse	96	1.18	48	191.78	57	0.56	48	197.48	57
	108	0.69	40	224.06	49	0.01	40	237.97	49
	120	0.27	33	263.85	41	-0.56	33	280.26	41

Adjoint Sensitivities

- Sensitivity to radiances assessed with adjoints of NAVDAS & NOGAPS
- Energy-weighted forecast error norm (moist TE-norm)

C = matrix of energy-weighting coefficients

f = NOGAPS forecast

t = verifying NAVDAS / NOGAPS analysis

x = NOGAPS state vector (u, v, θ, q, p_t)

$$e_f = \left\langle (\mathbf{x}_f - \mathbf{x}_t)^T, \mathbf{C}(\mathbf{x}_f - \mathbf{x}_t) \right\rangle$$

e_f has units of J kg^{-1}

$\langle \, , \, \rangle$ = scalar inner product

Langland and Baker (Tellus, 2004), slide courtesy of Rolf Langland

Ob Impact Calculation

Sensitivity gradient in observation space

NAVDAS adjoint

0.5 deg, current to ops version of NAVDAS

$$\frac{\partial (e_{24} - e_{30})}{\partial (\mathbf{y} - \mathbf{H}\mathbf{x}_b)} = \mathbf{K}^T \left[\frac{\partial e_{24}}{\partial \mathbf{x}_a} + \frac{\partial e_{30}}{\partial \mathbf{x}_b} \right]$$

Observation Impact

(J kg^{-1})

$$\delta e_{24}^{30} = \left\langle (\mathbf{y} - \mathbf{H}\mathbf{x}_b), \frac{\partial (e_{24} - e_{30})}{\partial (\mathbf{y} - \mathbf{H}\mathbf{x}_b)} \right\rangle$$

Innovations assimilated for Xa

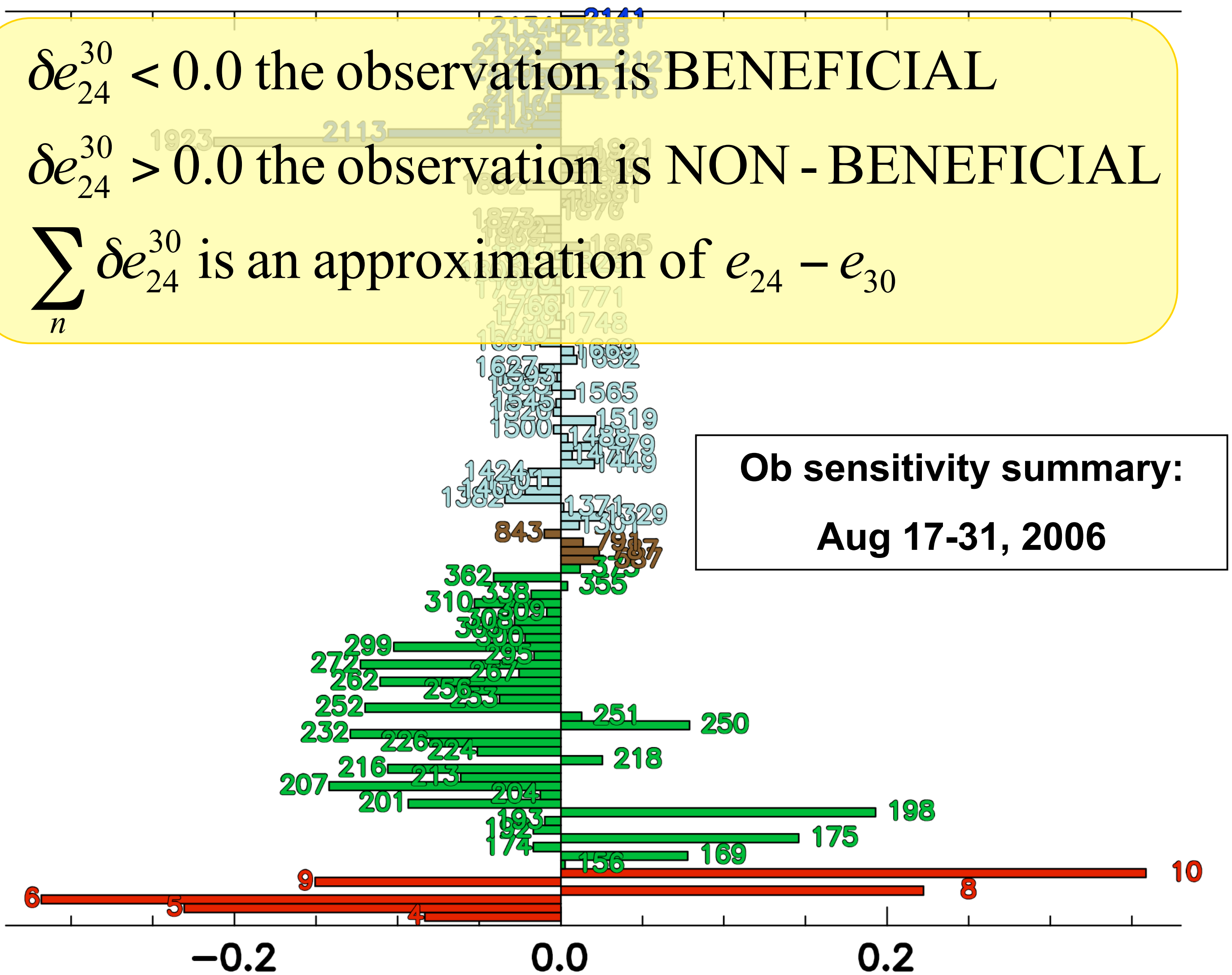
Langland and Baker (Tellus, 2004), slide courtesy of Rolf Langland

Observation Impact

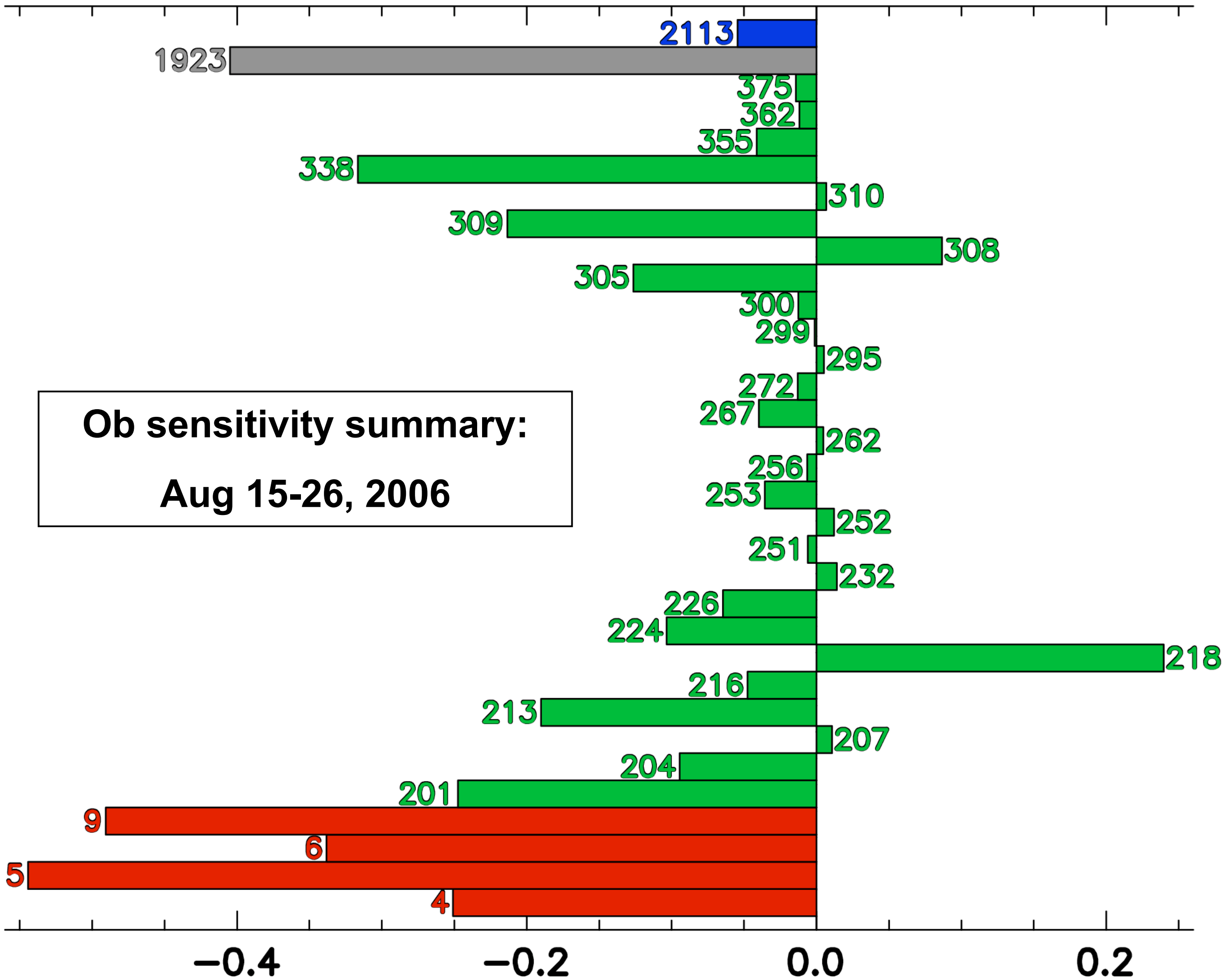
$\delta e_{24}^{30} < 0.0$ the observation is BENEFICIAL

$\delta e_{24}^{30} > 0.0$ the observation is NON - BENEFICIAL

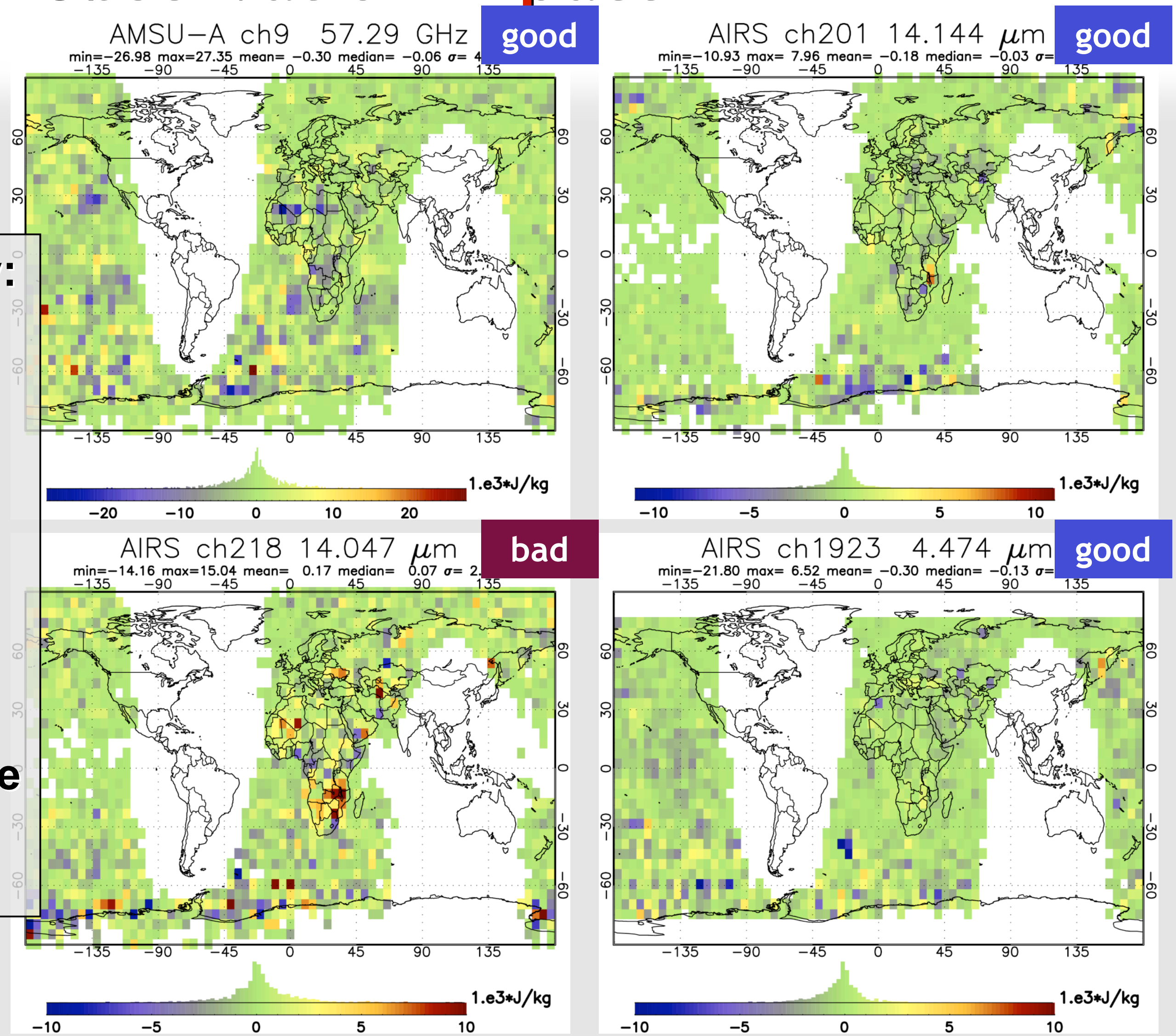
$\sum_{n} \delta e_{24}^{30}$ is an approximation of $e_{24} - e_{30}$



Observation Impact



Observation Impact



Ob sensitivity summary:

Aug 15-26, 2006

spatial distribution shows strong impacts are generally outliers

beneficial channels have slightly positively skewed distributions

1DVAR preprocessor

GOAL: improve atmospheric profiling over land
improve the Land Surface Temperature (LST)
reduce rejects over desert & elevated terrain

ISSUES:

- true background land emission (validation)
- uncertainty in land surface temperature analysis
- behavior of surface emission characteristics (scales)

How do the emission characteristics vary ?

- canopy properties
- soil properties
- surface roughness effects

1DVAR preprocessor

- Combined microwave and infrared
    - AMSU/A, AMSU/B, and HIRS/3
    - *AMSU, AIRS under development*
  - Retrieve
    - profiles of T,q
    - Land Surface temperature (LST) – single value
    - Surface emissivity (spectrally)
  - *a priori*
    - Atmospheric profiles
      - NOGAPS 3,6,9 hr forecast interpolated to observation
      - error covariance global
    - Infrared Emissivity
      - Indexed surface type to spectral library
      - error covariance from retrieval statistics, **NO** channel correlation
    - Microwave Emissivity
      - JCSDA MEM
      - error covariance from retrieval statistics

Ancillary Data

- Vegetation Data (1km – global)
  - static (based largely on AVHRR 1992)
  - needed for indexing and input to JCSDA MEM
- Soil Data (1/12th degree – global)
  - static, modeled in many regions
  - needed for indexing and input to JCSDA MEM
- Snow cover
  - Air Force product
- Sea Ice
  - NRL in-house analysis
- ASTER spectral library
  - Infrared spectra of soils and vegetation

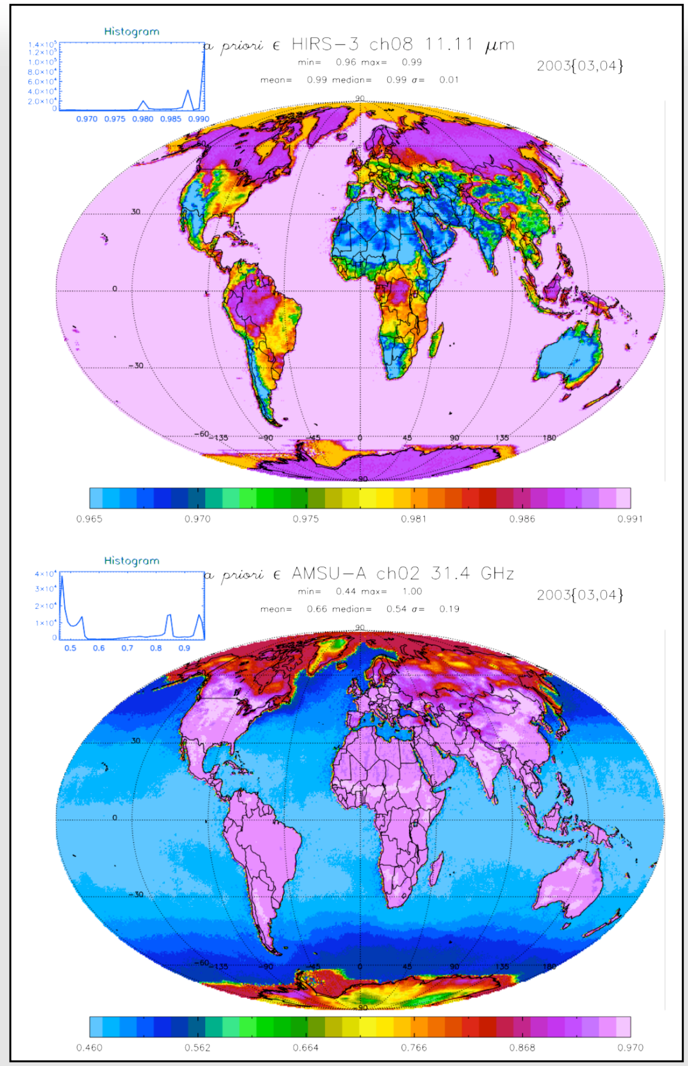
Initial emissivity estimate

Infrared:

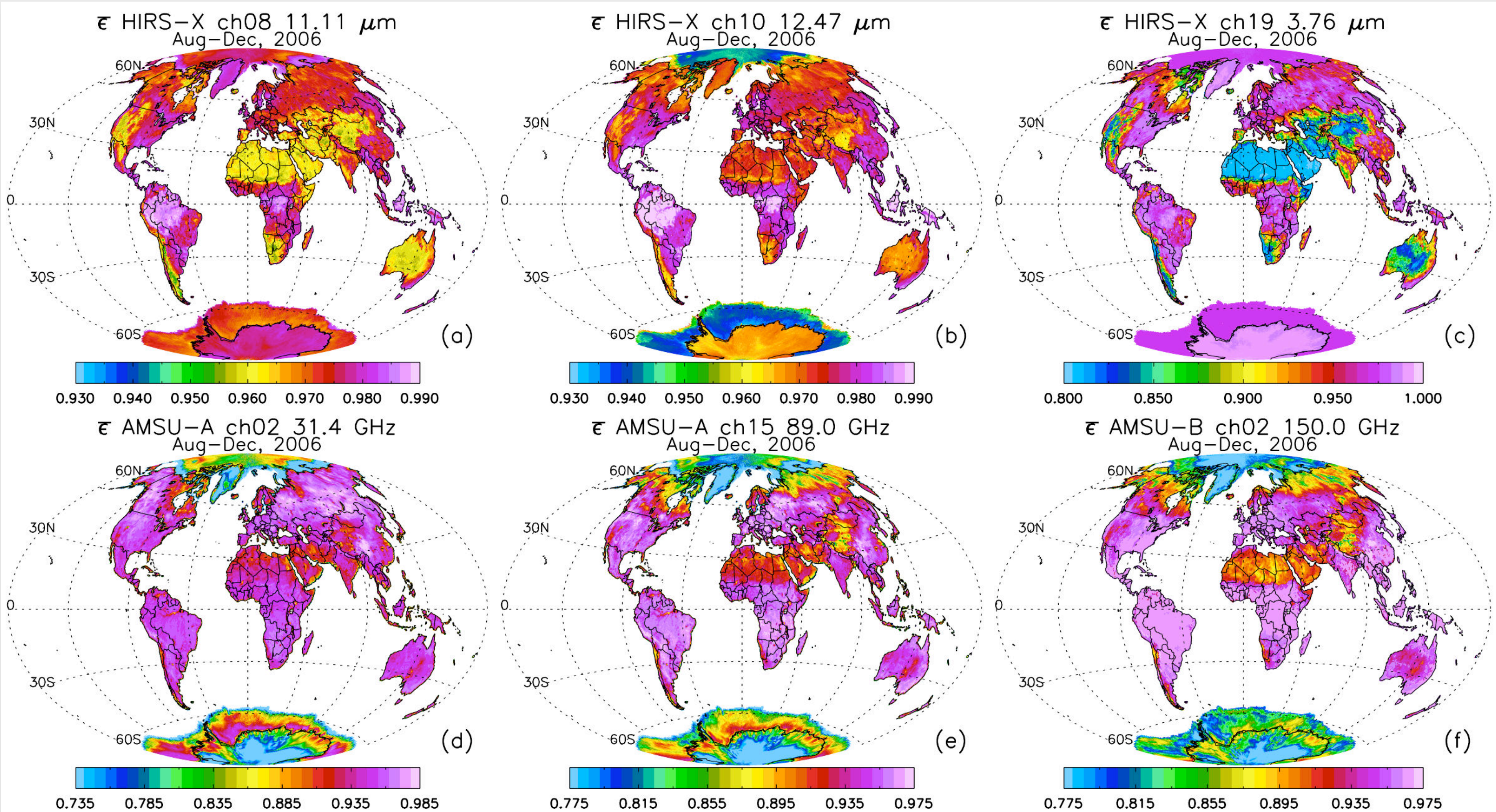
Land Databases indexed to spectral library

Microwave:

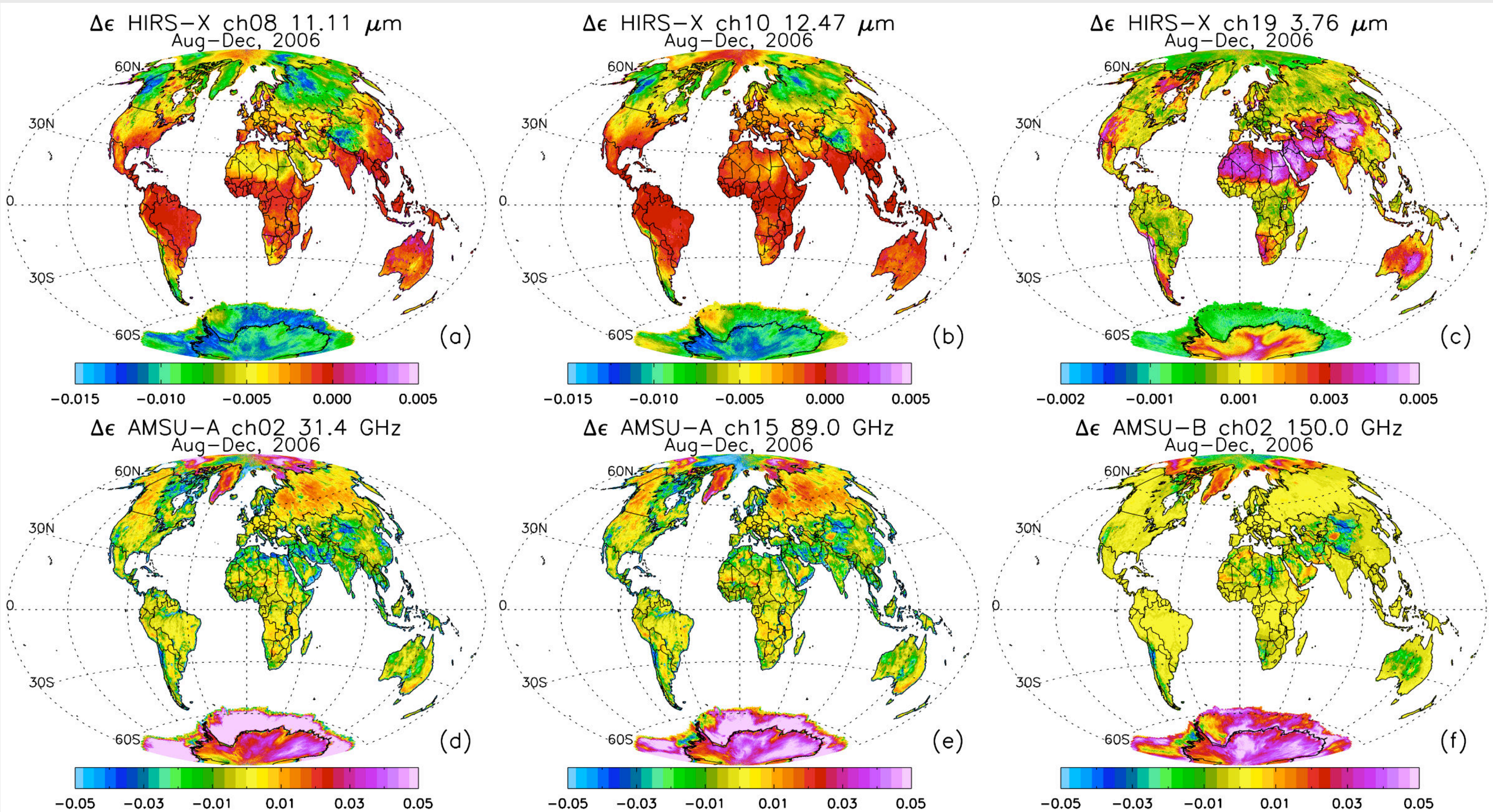
JCSDA MEM



1DVAR retrieval



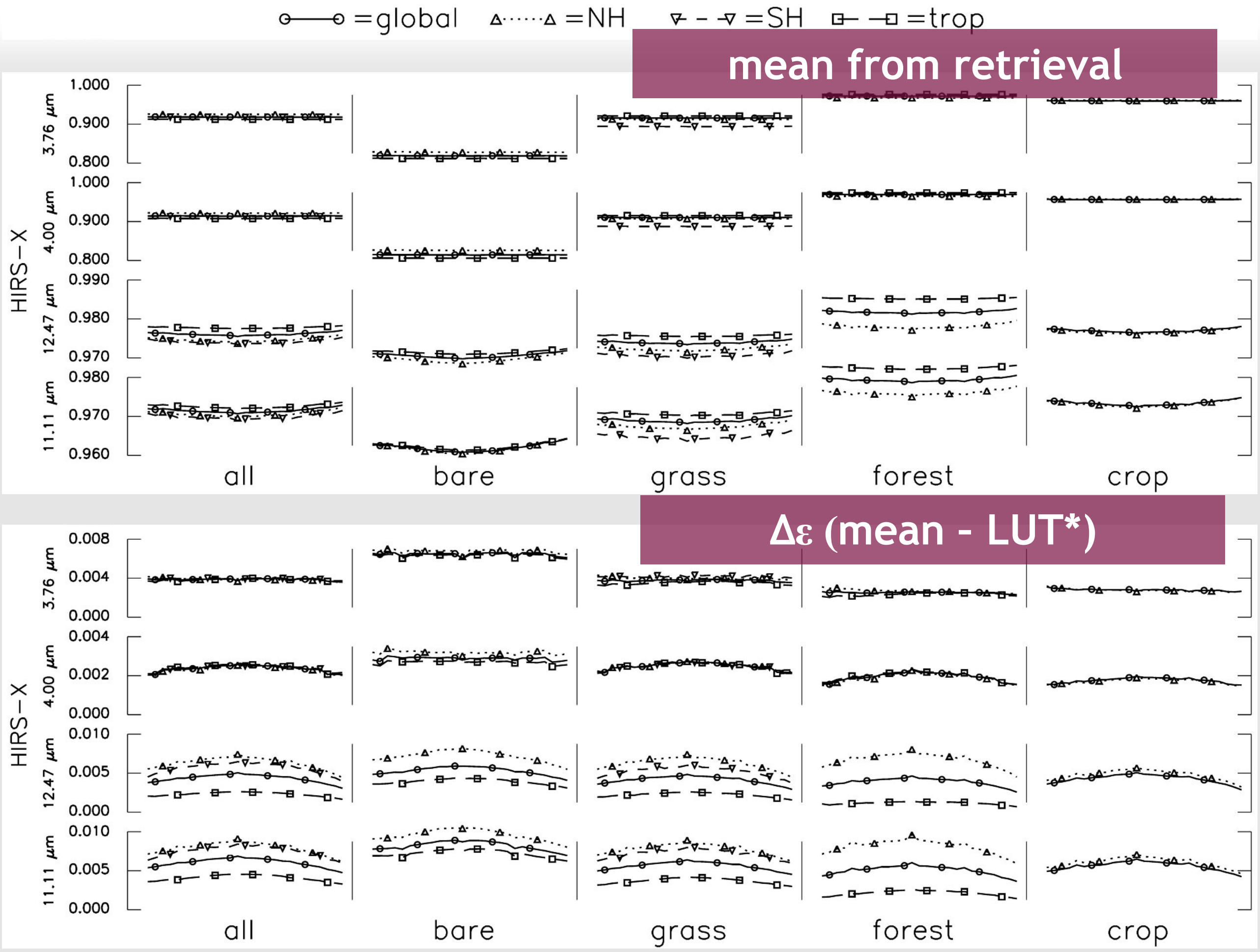
1DVAR retrieval



Scan Dependence

investigation indicates weak dependence

empirical correction possible



*LUT: look-up-table, emissivities from ASTER spectral library indexed to soil and vegetation databases

Summary

-AIRS assimilation cycling in NRL NAVDAS/NOGAPS system

-forecast impacts mixed, continuing to broaden study, examine quality control, bias correction

-observation sensitivities helping to guide channel selection assess sensor performance

Future Work

-AIRS experience to help guide transition to and use of IASI

-1dvar preprocessor used to estimate effective land surface emissivity and assimilate sounding channels over land

-NAVDAS operational with COAMPS, test regional assimilation

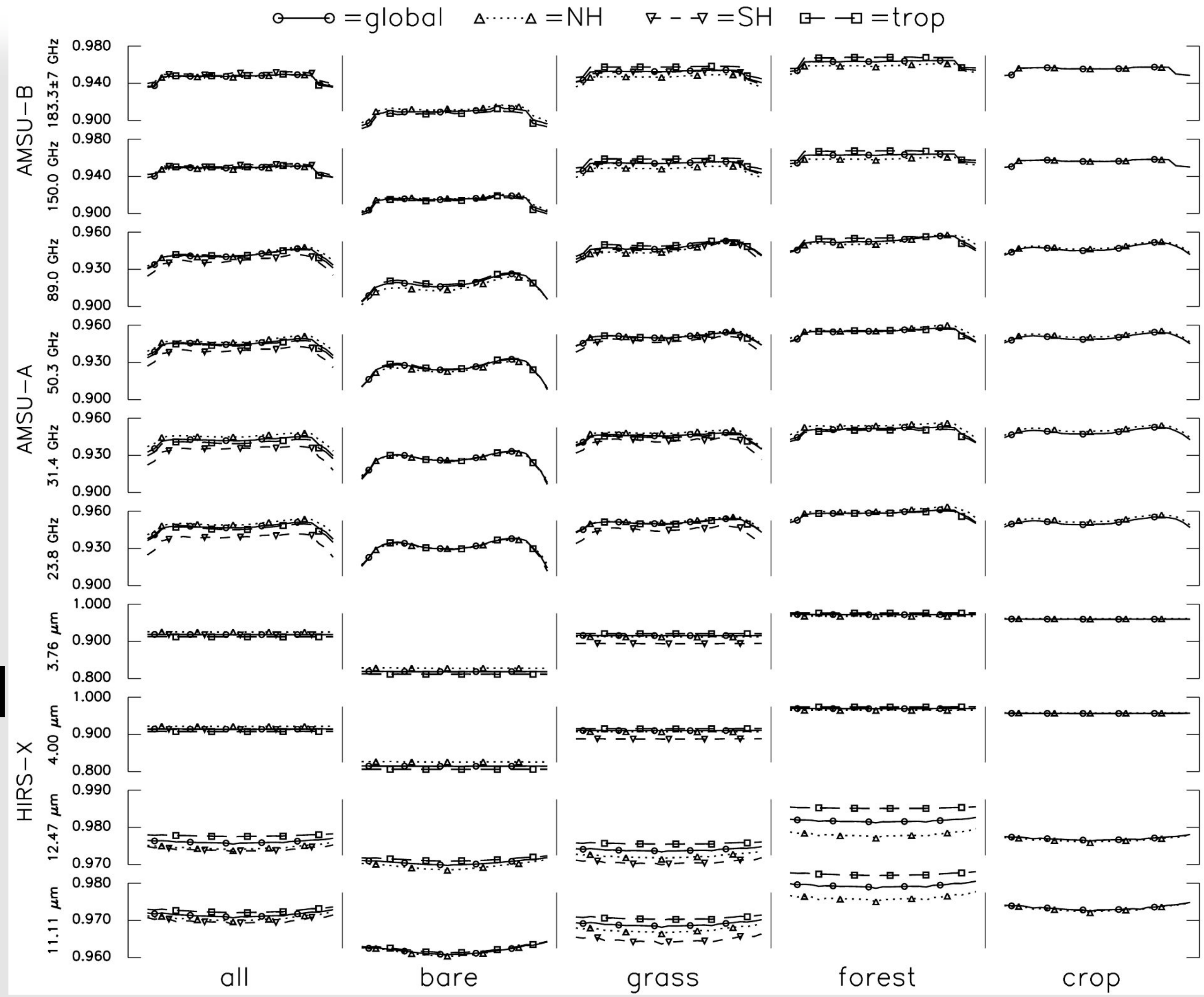
- Cloudy radiance assimilation with COAMPS (5km inner nest)

- NAVDAS-AR (4DVAR) better scalability with increase spectral spation observation density

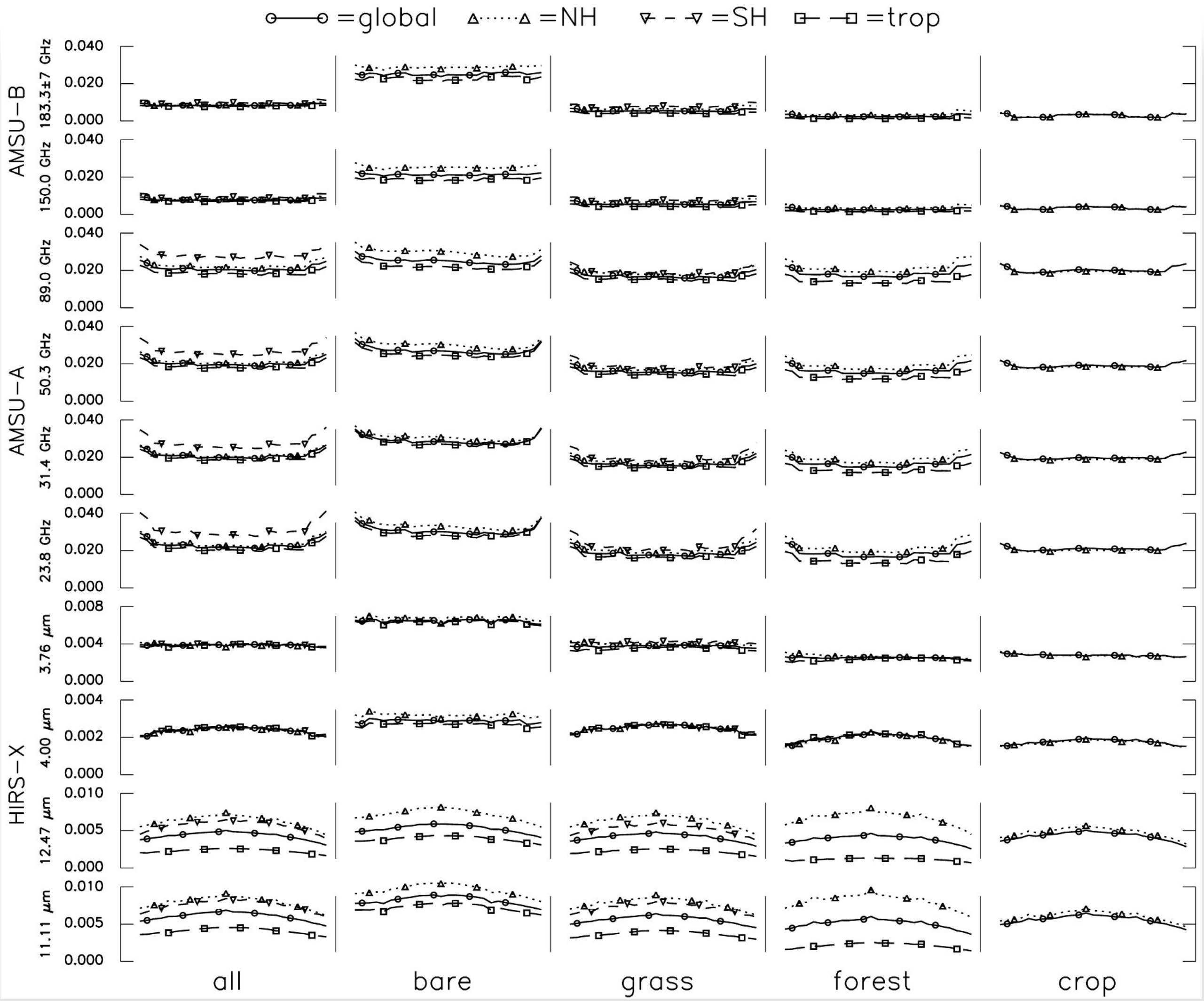
Scan dependence

greatest at lower freq

dampens with increasing freq & vegetation



Scan dependence



MEM generally good, slight overcorrection at edge of scan

IR small dependence